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Logistics Management Institute

# Economic Retention Within the Department of Defense

LG301T1

December 2003

Dennis L. Zimmerman

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Economic Retention  
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## Executive Summary

When to buy inventory and how much to buy are often touted as the fundamental questions to efficient and effective materiel management in both the private and public sectors. But a third question—one not directly related to buying stock—is equally fundamental to efficient and effective materiel management within the Department of Defense: How much stock should be retained above normal operating levels?

This question has long been the subject of debate. Some argue that any stock above normal operating levels is unnecessary and should be disposed of to avoid the cost of storage and to gain the financial return from its disposal. Opposing that argument is the savings that occur when retained stocks reduce or eliminate future repurchase or repair costs for an item, which are substantially higher than storage costs and returns from disposal. Therefore, most agree that, if stock is more economical to keep than to dispose of, it should be retained.

In its materiel management regulation, the Department of Defense has adopted this economic rationale to define economic retention stock (ERS) and to provide policy requirements and procedures for its determination. In recent years, Congress and the General Accounting Office have questioned the economic validity of those requirements and procedures. In response, the Supply Chain Integration Office of the Deputy Under Secretary of Defense for Logistics and Materiel Readiness (DUSD[L&MR]) tasked the Logistics Management Institute to examine if and how retention policy requirements and procedures could be improved.

## IMPROVING UPON CURRENT POLICY

Current policy states that DoD materiel managers should use an economic analysis that balances retention and disposal costs to determine ERS. To improve upon this policy, LMI sought a computational algorithm that would embody all of the costs of retention and disposal and allow materiel managers to find the most economical amount of stock to retain for items they manage.

We tested a variety of models (from mathematical optimization models to less sophisticated models), some of which are currently used by the military services and the Defense Logistics Agency (DLA). In our tests, we used actual FY1996–FY2002 data to evaluate retention decisions for 1,068,540 DLA consumable items and 101,747 Air Force reparable items. (We were not able to collect sufficient histories for Army and Navy items to include them in our testing, but we have no reason to believe they would differ from the consumable and reparable items we did test.) We judged the performance of each model based on its total net savings over the 7-year period.

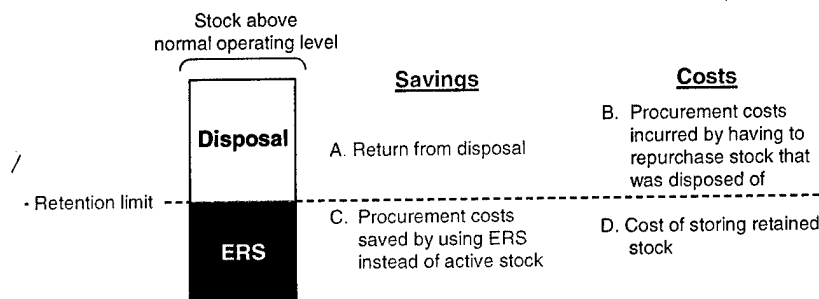
## SURPRISING RESULTS

Our testing revealed the following:

- ◆ Simple models using extended years of supply (30 years or more) outperformed the more sophisticated optimization model. In most cases, the retain-all model produced the greatest savings (assuming the Department has sufficient warehouse space).
- ◆ Adding options, such as retaining a minimum number of units or not permitting ERS for items with extended histories of no demand, improved the net savings for most models.

To explain these results, we examined each of the factors that affect retention and disposal decisions, as depicted in Figure ES-1.

*Figure ES-1. Retention Decision Savings and Costs*



Because the dollar return from disposal is small and the cost of storage is even smaller while the cost of procurement or repair is large, we expected the costs saved by using an ERS approach would play a big role in the retention decision. And, they did. We also found the costs incurred when materiel is disposed of and must be repurchased later were a major contributor and were key to the dominance of the simpler models that called for the retention of more stock.

## BEHIND THOSE RESULTS— HIGH DEMAND VARIABILITY

Although DoD inventory models allow for demand variability, they assume the average demand for items is relatively stable from year to year. Without this stability, DoD materiel managers could not predict future demand and accurately set retention limits.

We examined demand variability for our two sets of data and determined the following:

- ◆ The mean and variance ratio for annual demand is extremely high, much higher than what is assumed in many inventory models.
- ◆ Such high ratios dramatically reduce the accuracy of forecasting models.
- ◆ Predictions of long-term demand (more than 2 years) that are based on extending demand forecasts or recent demand histories are highly unreliable with one exception: Items experiencing zero demand over several years have a high probability of experiencing zero demand in the future.

Based upon these findings, we realized the validity of projected future stock usage, which is part of most retention models, is small. In the long term, demand may occur at a far different pace (either much slower or faster), and huge peaks and valleys in demand patterns should be expected. Without accurate long-term forecasts of future demand, optimization models are not able to accurately set retention limits and may produce limits that result in less-than-optimal savings.

## WHAT TO DO

Our findings support the conclusion that, without the ability to produce accurate long-term demand forecasts, DoD materiel managers should err on the side of retaining more stock for the items they manage. We are not recommending they should retain all stocks in all cases. Inventory should be disposed of when items have become obsolete or out of date. Moreover, our tests of DLA items using the retain-all model showed a 20-percent increase in on-hand stocks in 6 years. If the growth in on-hand stocks requires additional warehouse space be acquired or built, then the cost of building or acquiring that space would outweigh savings from retention.

Our tests indicate that years-of-demand models with very large numbers of years and with minimum-level or no-demand options perform well and don't increase stock levels. For example, our tests of DLA demand-based items with 50 years of stock retention and a 7-years-of-no-demand option achieved 92 percent of the savings of the retain-all model and actually showed a 52 percent decrease in on-hand stocks after 6 years. Such models also provide managers with parameters

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to change retention limits when they need to. The retain-all model does not provide these parameters and, if applied year after year, will only increase stock levels to the point they are uneconomical.

We recommend DoD procedural guidance for setting economic retention limits should call out the use of minimum-retention limits as a viable means of dealing with the uncertainty in forecasting long-term demand. In accordance with DoD policy, the DoD components should review their retention methodologies at least annually and adapt the general models and options in this analysis to their specific items.

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# Chapter 1

## Overview

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Materiel managers at DoD inventory control points<sup>1</sup> serve as wholesale suppliers for the millions of items that are demanded by military customers around the world. To meet that demand, materiel managers acquire and maintain inventories using requirement levels that are built around forecasts of customer demand. Over time, when demand for an item declines below the forecast used to compute its requirement level, managers may end up with too much stock. If that happens, materiel managers must decide how much stock should be retained and how much should be sent to disposal.

To make this decision, materiel managers rely on economic retention limits that set the maximum level of stock that should be retained. This report explains how they should set cost-effective retention limits.

## OUR TASK

The Supply Chain Integration Office of the Deputy Under Secretary of Defense for Logistics and Materiel Readiness tasked LMI to examine whether current economic retention policy requirements and procedures could be improved.

The need for this study arose from the following events:

- ◆ In May 2001, the General Accounting Office (GAO) published a report that was critical of DoD's approach to item retention and disposal decisions. GAO concluded that DoD materiel managers did not have a sound analytical approach to materiel retention because they
  - have moved away from economic models and use judgmentally determined levels,
  - employ factors that are not supported by analyses and use assumptions that lack consistency with government-wide and department-wide guidance, and
  - do not conduct annual reviews of their retention approaches as required by DoD guidance.

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<sup>1</sup> The term "inventory control point" refers to an organizational unit or activity within the DoD supply system that is assigned the primary responsibility for the materiel management of a group of items either for a particular military service or for DoD as a whole. Materiel management includes provisioning, cataloging, requirements determination, acquisition, distribution, maintenance, and disposal. Individuals performing these functions are materiel managers.

- ◆ A congressionally mandated independent study examined economic retention within the Department of Defense between 1992 and 2000.<sup>2</sup> The study revealed that the current methodologies for retaining stock were cost-effective but a new methodology—one based on periods of no demand—would be more cost-effective.
- ◆ Today, the Army, Navy, and Defense Logistics Agency (DLA) are working to replace their automated materiel management systems with commercial off-the-shelf (COTS) enterprise resource planning (ERP) software. Such software creates a new environment for conducting materiel management business—an environment in which traditional practices, such as setting economic retention limits, may need to be revised.

## OUR APPROACH

There are two basic types of models for setting retention limits. One involves a limit equal to a level of stock (usually, an expected number of years of future demand); the other involves a limit equal to the stock level in which the costs of retaining stock equal the costs of disposing of stock. Both types can be accommodated within current and planned materiel management systems. In the case of an ERP environment, the accommodation may involve setting system parameters or feeding levels developed by non-ERP software.

Variations do exist for each of the model types. For the level-of-stock models, variations can involve an alternative number of years or different starting points for setting limits. For models that balance costs, variations use different values for cost factors and, for reparable items, they use different demand streams. In addition, policy options (such as setting minimum limits or zero limits for items with extended periods of no demand) can be combined with either type of model.

## Judging Alternatives

Given that feasibility is not an issue, our analysis focused on identifying the best model or models for setting retention limits and the policy implications. For the purpose of our study, the best model would be the one that produces the greatest savings or the lowest cost to the government. The worst model would result in the lowest savings or greatest cost to the government.

Our approach corresponds with current DoD procedural guidance on setting economic retention limits, which says the maximum level of economic retention stock (ERS) for an item should be based on an economic analysis that balances

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<sup>2</sup> Logistics Management Institute and Center for Naval Analyses, *Independent Study of Secondary Inventory and Parts Shortages*, Report LG009R1, July 2001.

the costs of retention and the costs of disposal.<sup>3</sup> (Chapter 2 has more on the current policy requirements and procedures on economic retention.)

## Important Points

Our analysis only included items that were in the DoD supply system from the beginning of FY1996 to the end of FY2002. Consequently, we excluded items that left the system or became obsolete during that time. An item becomes obsolete either because it is replaced or phased out, or because the system that the item is part of is replaced or phased out.<sup>4</sup> With no potential future demand for such items, there is no need to retain their stocks.

The retention decision determines how much stock above the maximum required level should be retained as ERS and how much should be disposed of. As such, the economic retention limit is not a requirement-based level like the safety level or order quantity. It also is not a level required to support normal operations; therefore, when stock drops below this level, it is not repurchased or replenished through procurement or repair. A retention limit is only indirectly related to procurement and repair in that

- ◆ the stocks being retained can preclude or reduce future procurements or repairs and
- ◆ the stocks being disposed of are not available to preclude or reduce future procurements or repairs.

## Measuring Effectiveness

To estimate the cost effectiveness of individual retention decision models, we replayed 7 years of history for DLA consumable and Air Force reparable items, starting with the actual stock levels at the beginning of the 7 years and then applying the actual demands and DLA and Air Force requirement levels over that period. For each model, we compiled the total savings over the 7 years from its retention and disposal decisions in response to actual demand.

## Tested Alternatives

Given the large number of possibilities, we could not test all model variations. We wanted to test a sufficient number of variations to identify which are more cost-effective. Because economic retention has long been an area of study, we did not expect to uncover any revolutionary findings. But, given the 7 years of data available to us, we felt we had sufficient item usage and demand histories across large populations of items to produce highly credible findings.

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<sup>3</sup> DoD 4140.1-R, *DoD Supply Chain Materiel Management Regulation*, May 2003, p. 55.

<sup>4</sup> Although not addressed in this report, phaseouts are part of DoD procedural guidance on materiel retention.

As previously mentioned, the populations studied involved DLA-managed consumable items and Air Force-managed reparable items. The DLA items were further categorized into

- ◆ demand-based, stocked items—referred to as quarterly forecasted demand (QFD) items because their inventory levels are based on quarterly forecasted demand;
- ◆ non-demand-based, stocked items—referred to as numeric stockage objective (NSO) items because their inventory levels are based on a numeric stockage objective; and
- ◆ non-stocked items.<sup>5</sup>

We tested these three categories of DLA items at the same time because we wanted to include in our simulation the actual migration of items between groups.

Chapter 3 discusses all the models we tested. Table 1-1 summarizes the model variations we tested within each item group.

*Table 1-1. Number of Model Variations by Item Group*

Model or group of models	DLA QFD items	DLA NSO items	DLA non-stocked items	Air Force reparable items
Zero retention	1	1	1	1
Years of demand	6			6
Years of demand above maximum required level	6			6
Numeric levels (multiple of NSO quantity)		6		
Numeric levels (number of units)			6	
Economic or net present value models	3			12
LMI model previously developed for Air Force items				11
No-demand option	20	20	20	
Minimum-level option	3	3	3	3
Retain all	1	1	1	1

To determine the maximum savings possible per group, we also constructed a perfect knowledge model. As its name implies, it uses our perfect knowledge of past demand to set future retention limits that maximize savings. The perfect knowledge model is useful for theoretical testing, but it is not a viable model for real-world application.

<sup>5</sup> Although an item may be managed as a non-stocked item, it may have stock. For example, if the item was previously managed as a stocked item, current stock could be stock remaining from when the item was stock.

## COMPUTATION OF SAVINGS

Chapter 3 addresses the different types of savings and costs that are associated with stock retention and disposal and explains how we estimated those savings. In brief, the savings and costs are as follows:

- ◆ The annual cost of storing materiel (calculated as 1 percent of its value)
- ◆ Savings from using the retained materiel instead of repurchasing materiel at its full value or (for reparable items) repairing materiel at its repair cost
- ◆ Revenue from materiel disposal (calculated as 5 percent of its value)
- ◆ Repurchase cost of materiel that is disposed of and later repurchased (calculated as the value of materiel).

The net savings is the sum of all of the above, where costs are negative savings.

## TEST RESULTS

This section summarizes the results presented in Chapter 4. While Chapter 4 shows the net savings for all variations we tested, here we only show sufficient results to provide a relative ranking of the models and their variations for each of the four item groups.

For all item groups, the zero-retention alternative produced negative savings (i.e., a net cost to DoD). That is why we excluded it from the following charts.

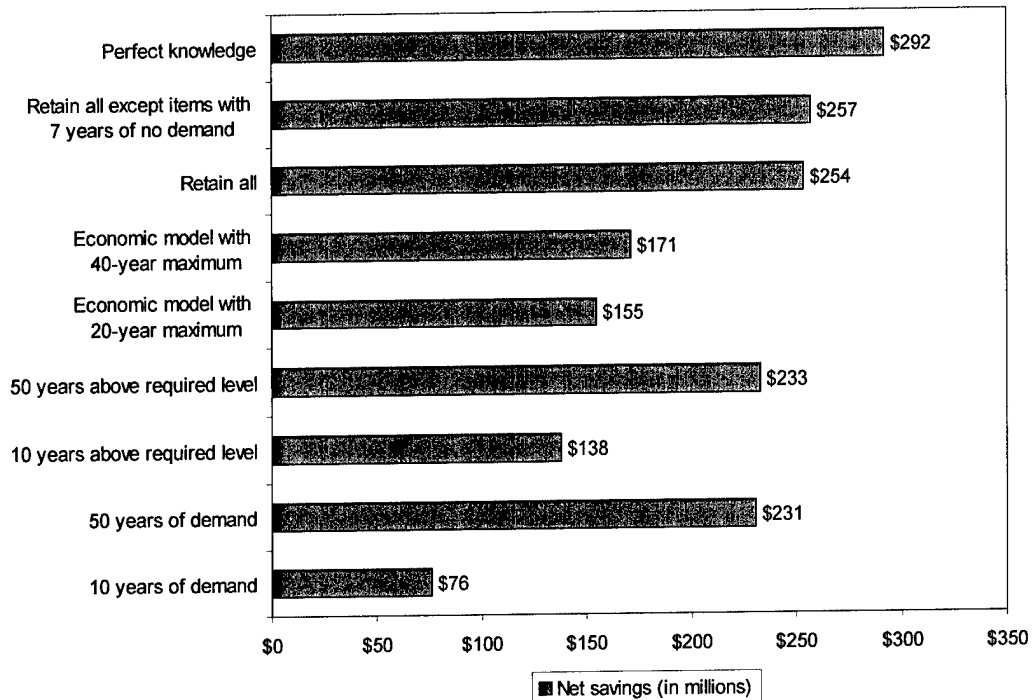
### Results for Demand-Based, Stocked Consumable Items

For DLA QFD items, we tested retention limits based upon the following:

- ◆ Years of demand
- ◆ Years of demand above required levels
- ◆ An economic model that balances costs
- ◆ The retain-all model
- ◆ One of the above plus
  - an option that assigns no ERS to items with years of no demand, or
  - an option that assigns a minimum number of units to limit.

Figure 1-1 compares the test results for several of the variations against the best possible results, which are represented by the perfect knowledge model. We excluded results for using the minimum-number-of-units option because it had little bearing on this group of items.

*Figure 1-1. Ranking of Models for DLA Demand-Based Items*



The results in Figure 1-1 indicate the retain-all model and the retain-all model with the years-of-no-demand option produced the greatest savings. The 50-years-of-demand model also produced high savings, while the variations of the economic model and the fewer years of demand produced lower savings. The high demand and consequently high usage of items in this group obviously supports high retention limits.

## Results for Non-Demand-Based, Stocked Consumable Items

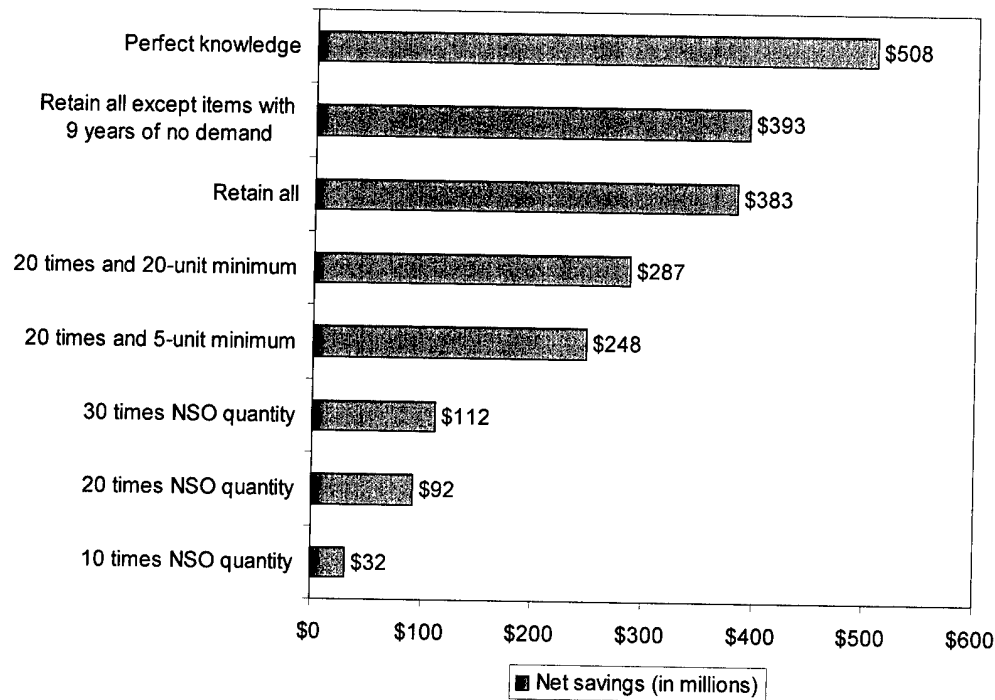
For DLA NSO items, we tested retention limits based upon the following:

- ◆ A numeric model that used multiples of the NSO quantity
- ◆ The retain-all model
- ◆ One of the above plus
  - the no-demand or
  - minimum-number-of-units option.



Figure 1-2 compares the test results for several of the variations against the best possible results, which are represented by the perfect knowledge model.

*Figure 1-2. Ranking of Models for DLA Non-Demand-Based Items*



Again, the retain-all model and the retain-all model with the years-of-no-demand option produced the greatest savings for this group of items. The addition of the minimum-number-of-units option significantly improved the savings from just using a numeric model that is based on a multiple of the NSO quantity. Having a minimum for the retention limit protected against the low and unpredictable demand that is characteristic of this group of items.

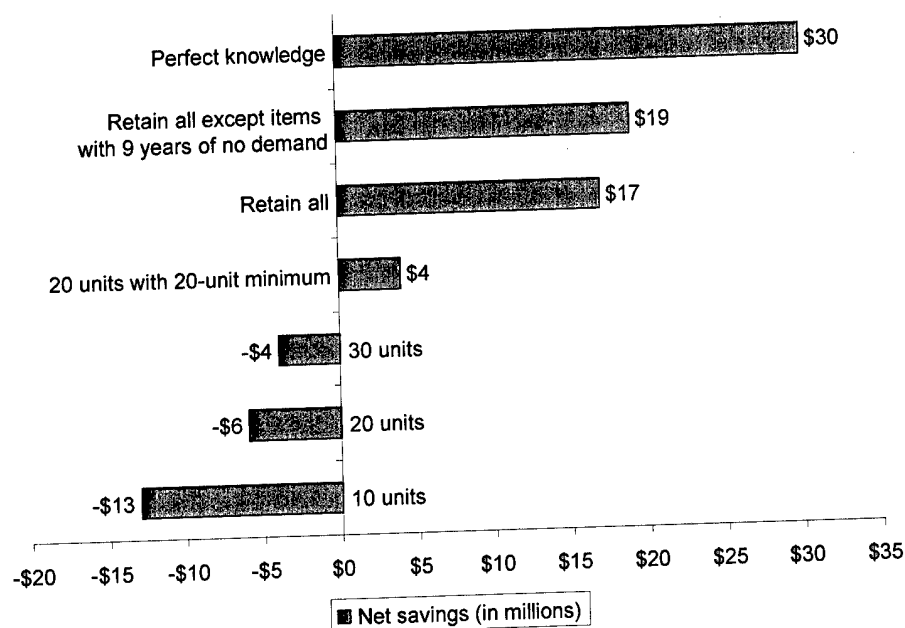
## Results for Non-Stocked Consumable Items

For DLA non-stocked items, we tested retention limits based upon the following:

- ◆ A numeric model that used a set number of units
- ◆ The retain-all model
- ◆ One of the above plus an option assigning a minimum number of units to limit.

Figure 1-3 compares the test results for several of the variations against the best possible results, which are represented by the perfect knowledge model.

Figure 1-3. Ranking of Models for DLA Non-Stocked Items



As was the case with the other DLA item groups, the retain-all model and the retain-all model with the years-of-no-demand option produced the greatest savings for this group of items. The addition of the minimum-number-of-units option again improved savings for the numeric model.<sup>6</sup>

## Results for Repairable Items

For Air Force repairable items, we tested retention limits based upon the following:

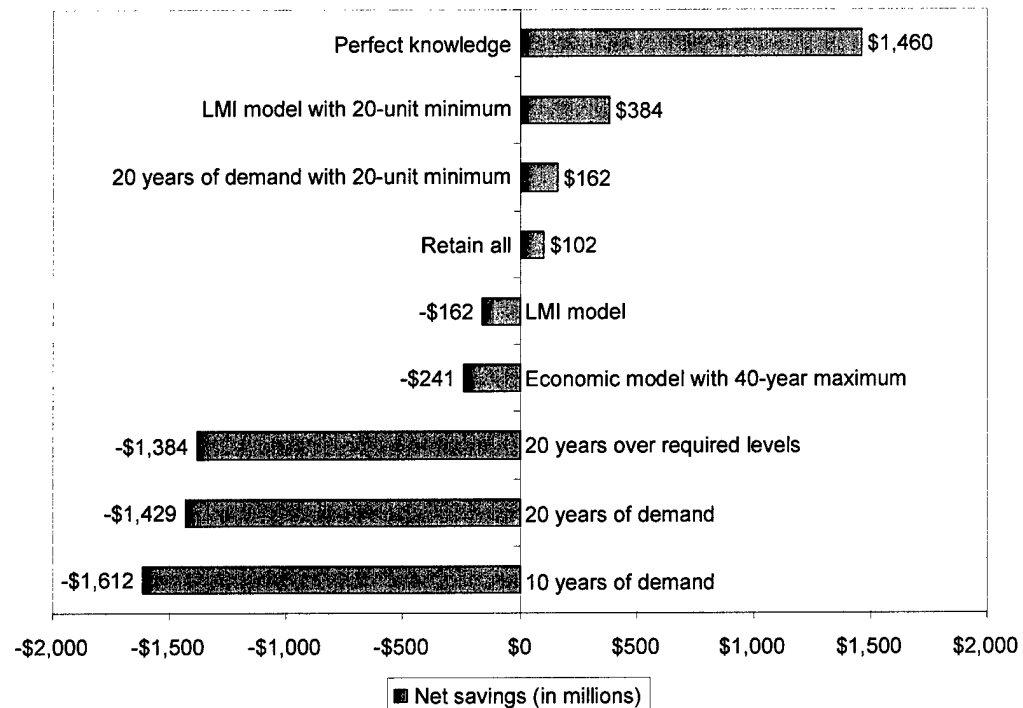
- ◆ Years of demand
- ◆ Years of demand above required levels
- ◆ An economic model that balanced costs
- ◆ A model LMI previously developed for the Air Force

<sup>6</sup> This result appears incorrect because the application of a minimum of 20 to an item that has a numeric limit of 20 should produce no change to the amount of stock retained. The difference is caused by the migration of items from stocked to non-stocked. For example, suppose an NSO item has an NSO quantity of zero but had 10 units of on-hand stock. If the retention limit is 20 times the NSO quantity, then the item's limit is zero and all 10 units are sent to disposal. If the item migrates in the next year to a non-stocked item, it would have zero stock available for possible use. However, suppose a 20-unit minimum applied to the same item. When the item was an NSO item, all 10 units would have been retained; and when the item migrated to a non-stocked item, all of those units would be available for possible use.

- ◆ The retain-all model
- ◆ One of the above plus an option assigning a minimum number of units to limit.

Figure 1-4 compares the test results for several of the variations against the best possible results, which are represented by the perfect knowledge model. (We did not have the data necessary to test the no-demand option.)

*Figure 1-4. Ranking of Models for Air Force Reparable Items*



As shown in Figure 1-4, the retain-all model and the other models with a minimum-quantity option were cost-effective; all other models were not. The cost effectiveness of the minimum-quantity option is again due to the low and unpredictable demand that is typical of items in this group.

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## WHAT CAN BE INFERRED FROM OUR TESTING

The fact that the retain-all model or models with a minimum-level option outperform years-of-demand and economic models was unexpected—given that they do not make use of item data and they lack sophistication. We speculated this finding might be related to demand variability. Our reasoning was as follows:

- ◆ The retain-all model and minimum-level option do not use demand forecasts to set retention limits.
- ◆ Years-of-demand and economic models use demand forecasts to set retention limits.
- ◆ If demand variability is high and results in inaccurate demand forecasts, the models that depend on demand forecasts should be less effective than models that do not.

To test our theory, we investigated demand variability for our items. We found that variability was indeed high; there was a wide dispersion of demand between years. Most items had 1 or more years of no demand across the 7 test years, and the statistical variance of those that had demand every year was much higher than what might be expected. We also found this high variability caused a high level of forecast error and made it difficult to determine when stock levels will be depleted. (Chapter 5 presents all of our findings.)

High demand variability adversely affects all inventory decision-making, causing stock buys to be too big or too small, excesses and shortages in on-hand inventories, and the premature release of materiel to disposal. As discussed in Chapter 2, high demand variability is also why retention limits are so important to the Department of Defense and why they warrant the periodic retention analyses dictated by DoD policy.

Although the retain-all model produced positive results in all cases, we would not recommend it as the best long-term model for all items. As part of our testing, we looked at how the stock on hand changed from one year to the next and found the on-hand stock increased

- ◆ 13 percent for DLA QFD items, 8 percent for NSO items, and 429 percent for non-stocked items—an overall increase of 20 percent; and
- ◆ 61 percent for Air Force reparable items.

In the long term, retaining all stock and disposing of no stock would significantly increase the need for warehouse space. If that space is not available, it would have to be acquired or built, and the associated costs could outweigh the savings from retention.

## POLICY RECOMMENDATIONS

Section C2.8.1.2 of DoD 4140.1-R, *DoD Supply Chain Materiel Management Regulation*, establishes economic analysis as the DoD methodology for determining economic retention. Nothing in our study revealed the need to change the in-depth analysis called for in the regulation. On the contrary, our findings show the tailoring of options and parameters in existing retention models to item populations can result in economic retention limits that produce significant savings.

Section C2.8.1.2 specifically says the DoD components should review their economic retention methodologies and focus on

- ◆ better analyses using forecasting models that account for long-term demand trends and
- ◆ improved cost estimates.

We recommend the DoD components also consider using minimum limits to account for difficulties in forecasting long-term demand.

The DoD components should review their retention methodologies annually, and adjust their limits up or down accordingly. Any increase or decrease in retention limits should be economically justified, however. Retention limits should not be reduced for the sole purpose of reducing inventories. As our study clearly showed, stocks that stratify above required levels have economic utility. Until that utility goes to zero, they should be treated as “assets” and not as “liabilities.”

## Chapter 2

# Principles of Economic Retention

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## WHAT IS ECONOMIC RETENTION?

Like most commercial suppliers, DoD materiel managers invest in inventory to satisfy the demands of their customers. That investment includes both consumable items, whose assets are not repaired but are discarded when they fail, and repairable items, whose assets experience failure when used and can be repaired (or condemned if found un-repairable during the repair process). Without any investment in consumable and repairable item stocks, customers would have to wait for procurement or repair actions to satisfy their requirements for materiel. Such delays could take weeks, months, or even years and could severely hamper military operations.

Because of the variability of demand and other factors, DoD managers may invest in inventory above immediate requirements; however, being over-invested in inventories can waste money. To avoid such waste, DoD materiel managers rely on economic retention limits to minimize unnecessary retention.

### The Official Definition

According to DoD 4140.1-R, *The DoD Supply Chain Materiel Management Regulation*, DoD wholesale inventories are stratified into four categories:

- ◆ Approved acquisition objective (AAO) stock—“the quantity of an item authorized for peacetime and wartime requirements to equip and sustain U.S. and Allied Forces, according to current DoD policies and plans.”
- ◆ Economic retention stock (ERS)—“stock above the AAO that is more economical to retain than to dispose of.”
- ◆ Contingency retention stock (CRS)—“stock above the AAO and above the ERS level, if one exists, that is held to support specific contingencies.”
- ◆ Potential reutilization stock—“stocks above that sum (AAO, ERS, and CRS)...[which] shall be reviewed for transfer to Defense Reutilization and Marketing Service as soon as practicable.”

Thus, economic retention is an approved level of stock at the DoD wholesale echelon of supply.

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## How Retention Fits into Traditional Inventory Control and Management

A materiel manager must invest in enough stock to satisfy an item's demand throughout its life cycle. For a consumable item, that investment is equivalent to its total life-cycle demand. For a reparable item, the demand for a replacement for a failed unit can be filled from the repair of the same unit or another failed unit. An additional unit is only purchased when the failed unit cannot be repaired and is condemned. Therefore, the investment for a reparable item is equal to its original cost plus the total number of condemnations during its life cycle.

For both consumable and reparable items, the required investment need not be made at one time; it can be made at different times throughout the item's life cycle. In fact, because demands and condemnations are virtually unknowable,<sup>1</sup> stocks for an item are normally purchased throughout its life cycle. Ideally, no stock should be purchased in excess of its investment quantity (as defined above) because, if stock is purchased and held in inventory until the end of the item's life cycle without being used, it will be sent to disposal, where only a portion of its cost may be recovered.

To avoid over-investment, it is important to know when and how much to invest. In their classic text on inventory analysis, Hadley and Whitin<sup>2</sup> discuss the general problems of controlling and maintaining inventories and cite two fundamental questions:

- ◆ When to replenish a stocked item?
- ◆ How much to buy as a replenishment quantity?

Although these questions are important, economic retention deals with still a third question. For an item with stock, how much should be retained and how much should be disposed of. If materiel managers could answer the first two questions perfectly, the need for economic retention would go away.

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<sup>1</sup> Due to events such as structure changes, weapon system life cycle extensions, etc. as well as the uncertainty in predicting failure due to wear.

<sup>2</sup> G. Hadley and T. M. Whitin, *Analysis of Inventory Systems*, Prentice-Hall Inc., 1963.

## RETENTION IS NOT AN INVESTMENT DECISION

Stocks within the AAO must be repurchased when consumed or condemned. This is not the case for stocks above the AAO; they are simply depleted when consumed or condemned. DoD materiel managers don't purchase or repair ERS or CRS. They have ERS and CRS because of changes in either demand, usage, or other factors.<sup>3</sup> In short, the accumulation of ERS and CRS is the result of earlier events and is not part of the retention decision.

## IF MADE INCORRECTLY, THE RETENTION DECISION CAN ITSELF CAUSE WASTE

Retention decisions determine when to retain stocks above normal requirements and when they should be sent for disposal. When disposing of stock, the government hopes to get some economic benefit from its sale or some other benefit from its donation; however, if DoD disposes of stock and later needs that stock to fill demand, it will need to repurchase it. Consequently, the retention decision could affect how many times stocks are purchased over the life of an item. Any repurchasing of stock that has been disposed of prematurely constitutes waste.

## WHY DOES THE DEPARTMENT OF DEFENSE NEED ECONOMIC RETENTION?

Ideally, materiel managers at inventory control points would have the means to precisely compute the future requirements or demands of their customers. Due to the variability of demand, however, this is not the case. As discussed in Chapter 5, DoD demand is extremely difficult to forecast. Two kinds of errors can occur.

- ◆ Demand can be over-forecasted and associated levels are greater than required to meet demand. As future forecasts decline to correct the error, inventory requirement levels also decline and actual inventories may go from being below the AAO to being above the AAO. Inventories that are above the AAO could then become ERS.
- ◆ Demand can be under-forecasted. Associated levels would be less than what is required to meet demand and shortages, or backorders could occur. The presence of economic retention stocks would decrease the risk of backorders, as extra stock would be available to satisfy demands above the forecast.

So forecasting errors can contribute both to the presence of ERS and to its use in filling demand; however, it is the use of ERS in filling demand that supports its retention. That usage establishes an economic argument that it is cheaper to retain extra stock to fill future demand than it is to dispose of stock only to repurchase it later to fill demand.

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<sup>3</sup> Factors include data errors in buying or setting requirements, incorrect provisioning, invalid requirements, application phaseout, and overbuying.



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The 2001 Congressionally mandated independent study concluded, “The current DoD program for retention and disposal is cost-effective.” The same study went on to say that additional savings could be achieved using a years-of-no-demand heuristic method.<sup>4</sup> That is why this study focuses on the best way to determine economic retention and not whether or not economic retention stocks should exist.

## HOW SHOULD ECONOMIC RETENTION BE DETERMINED?

The basis for determining ERS is cost-effectiveness. If the retention of stock saves the government money, it should be retained. If it does not, it shouldn’t be retained and is not ERS. As stated in DoD 4140.1-R, the setting of “the maximum level of ERS for an item should be based on an economic analysis that balances the costs of retention and the costs of disposal.”<sup>5</sup>

This procedure for setting economic retention limits falls out of the general government policy for determining cost-effective programs. OMB Circular A-94<sup>6</sup> presents guidelines and discount rates for benefit-cost analysis of federal programs. A-94 provides general guidance on how to analyze cost-effectiveness and specific guidance on the discount rates to be used when evaluating federal programs that have benefits and costs distributed over time.

The DoD economic retention program involves two alternatives: Retain stock for demand in a given future year, or dispose of it. Because each alternative has measurable costs that extend for 3 or more years in the future, A-94 principles apply:

A program is cost-effective if, on the basis of life cycle cost analysis of competing alternatives, it is determined to have the lowest costs expressed in present value terms for a given amount of benefits.

In the case of the DoD economic retention program, the period of analysis is the number of years that stock is being retained. Benefits equate to savings or cost avoidances, which vary by year. The most cost-effective number of years for retaining stock is the year the present value analysis shows that retention savings exceed disposal savings, while the analysis of the next year shows disposal savings exceed retention savings.

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<sup>4</sup> A heuristic is a rule of thumb, simplification, or educated guess that is offered as a decision-making tool. Unlike a model or algorithm, it does not have a theoretical basis nor does it guarantee the best solution.

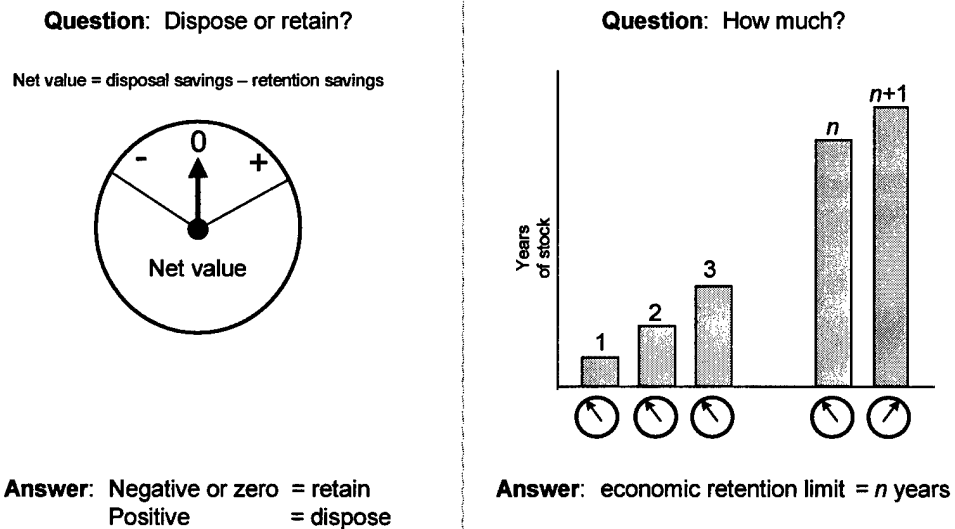
<sup>5</sup> DoD 4140.1-R, *DoD Supply Chain Materiel Management Regulation*, May 2003, p. 56, paragraph C2.8.1.2.1.

<sup>6</sup> OMB Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, 29 October 1992.

Figure 2-1 illustrates the ideal process for determining the most cost-effective number of years of retention for an item. The steps in the process are as follows:

- ◆ Starting with year 1, use discount factors to express the present value of savings if stock is retained and the present value of savings if stock is not retain or is disposed of.
- ◆ Subtract the present value savings for retaining stock from the present value savings for disposing of stock to arrive at the discounted net value.
- ◆ If the discounted net savings are positive, add 1 to the number of years and compute a new discounted net value. If this value is negative, subtract 1 from the number of years to arrive at the optimal number of years.

Figure 2-1. Basics of Retention Analysis



This ideal assumes knowledge of future year costs and demand. In practice, this knowledge doesn't exist; in its place, current cost estimates and demand forecasts must be used. Moreover, to simplify the automation of the process, limits are often developed for item populations and not for individual items. In any case, the savings that are considered in the process are the same.

## Savings from Disposing of Stock

The savings from disposing of stock are twofold: savings in storage costs and revenues from disposal. If we retain stock to fill demand in future year  $n$ , we would incur the annual costs of storing that stock for  $n-1$  years. If we decide not to retain that stock, we would not incur the costs. Storage costs involve the cost of warehousing the stock in a secure and covered area and the cost of maintenance to prevent deterioration.

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Sales revenue is an immediate benefit normally associated with the disposal of stock; however, the disposal process has its own associated costs, as it involves marketing excess items—first internal to the government and then externally. If the excess item is disposed of as a donation, then no revenue is acquired. If the item must undergo demilitarization, that process has expenses; and the demilitarized materiel is only good for sale as scrap. Given these possibilities, we talk in terms of the net return from disposal versus the total return from disposal.

## Retention Savings

The savings from retaining stock involve the avoidance of future reprocurement costs. By not disposing of the stock already procured and on hand for some future year  $n$ , we avoid the costs of procuring the stock for a second time so that we have it available to satisfy demand in that year. The costs are the administrative or ordering costs associated with a procurement action and the purchase price of the materiel. Savings would therefore be the sum of these two costs.

(In actuality, if no demand occurs in year  $n$  or the demand for previous years is lower than expected and stock is carried over to fill demand in year  $n$ , then no reprocurement costs and no cost avoidance would occur. To a lesser extent, if the demand for year  $n$  is lower than expected or some stock carryover fills a portion of the demand in year  $n$ , then savings would be less than expected. These possibilities point to the importance of having the best possible forecasts of future demand and giving consideration to demand variance when computing savings.)

## SUMMARY

In this chapter, we established the role of economic retention in DoD inventory management. The rest of this report deals with the best way to carry out that role.

In the next chapter, we discuss different ways to determine economic retention and how we tested them.

## Chapter 3

# Model Testing

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This chapter reviews the cost criteria that we used to evaluate retention models and the alternative models that we tested.

## COST CRITERIA

Because ERS is retained solely on the basis of costs, cost performance is the obvious source for evaluating economic retention models. As noted in Chapter 1, the best model would produce the greatest savings, while the worst model would produce the least cost savings.

This approach to judging retention models is not new. Historically, DoD logisticians have used cost to study and select their models. The problem in setting economic retention levels is not what to do, it is how to do it. Specifically, how should costs be expressed in the model, what are their current values, and how sensitive are the costs and overall results to the factors used in the computation of costs?

In this study, we considered both tangible and intangible costs and estimated their value for purposes of testing. In what follows, we discuss how we made those cost estimates.

## Tangible Costs

As discussed in Chapters 1 and 2, we know that the following tangible costs and savings apply:

- ◆ Stock that is retained incurs storage costs, but it also benefits from the cost avoidance or savings realized when it is used to fill demand.
- ◆ Stock that is not retained benefits from the net return from disposal but may incur the cost of reprocurement if it is later needed.

## STORAGE

If stock is retained and subsequently not used in a year, then an annual storage cost applies. That cost is the marginal cost of storage and is normally computed as a percentage of the value of the materiel being retained. Typically, DoD logisticians have used a value of 1 percent for all items. For example, if an item had an acquisition cost of \$500, and 100 units were stored for a year, the value of the stock stored for a year would be \$50,000, and the annual storage cost would be \$500.

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This approach assigns the same cost to items with a low cost and high number of units in storage as it does to items with a high cost and a low number of units stored. For example, if an item had an acquisition cost of \$5 and 10,000 units or if it had an acquisition cost of \$50,000 and 1 unit was stored for a year, it would have the same \$500 storage cost.

Aside from the obvious disparity with the 1 percent rule, the 2001 independent study cited the following additional problems with the determination of the marginal cost of storage:<sup>1</sup>

- ◆ Would the cost of storage change if only a few units of an item were removed from a storage location?
- ◆ If it changes, how would it change linearly as assumed in the use of 1 percent?

We elected to go with the traditional approach to costing storage. And, although the storage costs collected in the 2001 independent study would have the actual percentage at slightly less than 1 percent, we used 1 percent in our testing.<sup>2</sup>

## DISPOSAL

Stock that is not retained is sent to disposal, where it is available for reutilization by other government departments or where it can be donated to non-government activities or sold to private businesses or individuals.

The savings from disposal is normally expressed as a percentage of the value of the materiel sent to disposal and is the net return based upon the revenue from sales less the cost of selling the materiel. The DoD Supply System Inventory Report (SSIR) assigns a value to potential excess that is equal to its acquisition price times the expected return from disposal or reutilization. Over many years, the normal return from disposal or reutilization is 2 to 3 percent of an item's value. In case our testing exposed new stock to reutilization, and that stock had a higher return, we used a slightly higher value of 5 percent.

## USAGE SAVINGS

### Savings Estimate for Consumable Items

When stock is within the AAO and is used to fill customer demand, it is normally repurchased for future demand requirements. However, when stock is retained above the AAO and some portion or all of it is used, it is not repurchased.

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<sup>1</sup> Logistics Management Institute and Center for Naval Analyses, *Independent Study of Secondary Inventory and Parts Shortages*, Report LG009R1, July 2001, pp. 4-10-4-12.

<sup>2</sup> The 1 percent value is based on warehousing costs that cover the care of materiel in storage as well as the maintenance of the storage facility. It does not include the cost of building new warehouses or otherwise acquiring new storage facilities.

Use reduces the need to use and repurchase stock within the AAO, thereby generating a cost avoidance or savings. That savings is the sum of the cost of the materiel that was used and the cost of a repurchasing action.

In this case, we used the actual acquisition price at the start of the year to compute the savings or cost avoidance when an item was used. The repurchasing cost depends upon its value. If that cost was combined with other actions on the same or different items, its value would be difficult—if not impossible—to estimate. Therefore, we used zero to facilitate our testing. Using zero underestimates the retention savings.

### Savings Estimate for Repairable Items

Because the demand for a repairable item may include the turn-in of an unserviceable item or item in need of repair, a repair action and not a repurchase action is most often required. The exception is when the repair action ends in a condemnation. Therefore, if the retained stock is serviceable (i.e., not in need of repair), its use to fill a demand saves the cost of repairing the turn-in item. Realizing the possibility of condemnation, we computed the savings as the item's repair cost times the percentage repaired plus the item's acquisition price times the percentage condemned.

If the retained stock were unserviceable (i.e., in need of repair), it would only be used if the stock being repaired to fill the demand were condemned. We estimated the savings to be the difference between the acquisition price and the repair price of the item times the percentage condemned. Table 3-1 demonstrates the above methodology for a hypothetical item.

*Table 3-1. Demonstration of Repair Savings Computations*

Cost element	Hypothetical value	Repairable unit	Non-repairable unit
A. Acquisition price	\$1,000	Included	
B. Repair cost/price	\$200	Included	
C. Difference in price (A-B)	\$800		Included
D. Percentage of demands without turn-ins	20%	Included	Included
E. Percentage with turn-ins	80%	Included	Included
F. Percentage repaired	90%	Included	
G. Percentage condemned	10%	Included	Included
Estimated savings for each unit retained and used to fill demand	Formulation Value	$A \times (D + E \times G) + B \times E \times F$ \$324.80	$C \times (D + E \times G)$ \$224.00

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## OFFSET COSTS

If materiel that is disposed of could have been used to fill demand sometime in the future if it had been retained, then the disposal action results in a cost. That cost is the sum of the cost of the materiel that would have been used to offset the procurement and cost of the procurement if it had totally offset the procurement action.

### Cost Estimate for Consumable Items

As we did in estimating reprourement savings, we used the actual acquisition price at the start of the year to compute the additional cost of having to repurchase stocks that were previously disposed of during our simulation. This required us to keep track of stock disposed of each year, and to identify when that stock could have been used to offset or reduce a buy.

### Cost Estimate for Repairable Items

We handled serviceable stock sent to disposal the same way we handled consumable item stock. Because unserviceable stock sent to disposal would still require repair before it could be used, the cost was the difference between the stock's acquisition price and its cost of repair.

## NET SAVINGS AND COSTS

We computed the net savings for each alternative retention model we tested as

$$net = us - sc - oc + ds, \quad [\text{Eq. 3-1}]$$

where

$net$  = net savings

$us$  = usage savings

$sc$  = storage costs

$oc$  = offset costs

$ds$  = savings generated by return on disposal.

If the net savings were negative, then the alternative produced a net cost.

## Intangible Costs

Another cost avoidance or savings associated with materiel retention is the cost of backorders—but it is a cost that cannot be measured. When demand exceeds stock levels, items are backordered. The retention of materiel above known requirements can reduce the size and number of backorders.

Although the effect of backorders is generally negative—down weapon systems, lost maintenance hours, and workarounds—the actual cost of a backorder is difficult if not impossible to compute.

In testing the possible effects of backorders on the retention decision, we used the value of the materiel backordered as the cost of the backorder. Using this approach, we assigned greater importance to high-cost backorders than low-cost backorders.

## ALTERNATIVE MODELS

The potential alternatives for determining ERS range between retaining all stock above an item's AAO to retaining no stock above its AAO, with intermediate alternatives based on years of demand or an economic algorithm.

### Alternatives at the Extremes

#### RETAIN-ALL MODEL

Retaining all stock above an item's AAO avoids all costs associated with repurchasing stock sent to disposal, but it incurs the maximum storage cost.

#### RETAIN-ALL MODEL WITH POTENTIAL-USE OPTION

A variation on the retain-all model, this alternative tries to avoid procurement costs by keeping all stock for demand-based items and limiting stock for non-demand-based items using potential-use criteria.

We employed the years-of-no-demand potential-use criteria. We retained no ERS for an item without any demand in 7, 9, or 12 years. Accordingly, we referred to this option as the no-demand option. This criterion was adapted from the 2001 independent study,<sup>3</sup> which showed that the more years an item had without demand, the more likely it would have no demand in the future.

Because DLA items have a date-of-last-demand field, we were able to test for the no-demand condition, starting with the first day of the simulation. And because the no-demand option is not tied to the retain-all model, we were able to test it with other models.

#### ZERO-RETENTION MODEL

The zero-retention alternative retains no stock above an item's AAO based upon the rationale that the probability of procurement is low and retention wastes holding costs and does not earn the revenue from disposal. Instead, the zero-retention model incurs the maximum repurchase cost.

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<sup>3</sup> Op cit., Report LG009R1, pp. 4-8-4-14.



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## PERFECT KNOWLEDGE MODEL

Although the zero-retention model and the retain-all model are at opposite extremes, neither model yields the highest level of combined retention and disposal savings. If a model has perfect knowledge of future demand, it could retain stock that would yield savings and dispose of stock that would not. Such a model would yield the highest combined savings.

Because perfect knowledge of future demand is not possible, this model is not viable; however, because we know the demand across the 7 test years, we constructed a perfect knowledge model. This perfect knowledge model provided a "best case" against which all other models can be compared.

## Level-of-Stock Alternatives

The level-of-stock approach is based upon the ideal process for determining ERS, which is discussed in Chapter 2. This approach assumes a breakpoint, at which the savings attained from disposing of stock outweigh the savings from retaining it.

## YEARS-OF-DEMAND MODEL

The years-of-demand alternative assumes the breakpoint is given in terms of years of demand. As such, this model requires the item have a forecast for future demand. DLA QFD items have the quarterly demand forecast (which we straight lined to get years of future demand). For Air Force items, we had 2 years of forecasted demand from their stratification (which we straight lined to get years of future demand).

This alternative sets the economic retention limit for an item equal to a given number of years of future demand. The number of years is a parameter that can be the same for an item population or can differ for different groups of items with a population. We tested this alternative model using the same parameter value for an item population.

## YEARS-OF-DEMAND-ABOVE-AAO MODEL

Like the previous alternative, the years-of-demand-above-AAO alternative assumes an economic breakpoint in years, but it starts at the item's highest requirement level rather than zero when setting that point. We tested this model using the same parameter values as above, but we added the AAO to arrive at our final retention limit.

## NUMERIC-LEVELS MODELS

Because DLA NSO items and non-stocked items have no demand forecast, we could apply neither years-of-demand models. The numeric-levels approach assumes the stock breakpoint can be expressed in terms of a numeric level.

For NSO items, that numeric level is a multiple of the NSO quantity. For non-stocked items, it is a number of units. To test the three groups of DLA items with similar models, we used the same parameter value in the years-of-demand model for the QFD items as in the numeric-levels models for NSO and non-stocked items.

## Economic Retention Models

Based upon how we determined economic retention, we tested the following retention models:

- ◆ A net-present-value retention model for consumable items
- ◆ A net-present-value retention model for repairable items
- ◆ A repairable-item model that distinguishes between serviceable and unserviceable assets and considers demand frequency when setting limits.

### NET-PRESENT-VALUE RETENTION MODEL FOR CONSUMABLE ITEMS

This model is based on the difference between the savings from disposing of an item's stock and the savings from retaining that stock. Mathematically, it is

$$NVP(n) = DS(n) - RS(n), \quad [\text{Eq. 3-2}]$$

where

- $n$  = the year of stock being considered for retention<sup>4</sup>
- $NPV(n)$  = the net-present value of the difference in savings between disposing of stock for future year  $n$  and retaining that stock
- $DS(n)$  = savings from disposing of stock for future year  $n$
- $RS(n)$  = savings from retaining stock for future year  $n$ .

<sup>4</sup> When we use the term "stock for future year  $n$ ," we mean the amount of stock equal to the expected demand for an item in future year  $n$ . Without a forecast of future demand for DLA NSO and non-stocked items, we cannot test this model on those items.

As seen in Figure 2-1, the retention-disposal decision is an iterative process. For each year  $n$  that  $NPV(n)$  is negative for some year  $n$ , the savings earned from retaining stock exceed the savings from disposing of it; therefore, the decision is to retain the stock. As year  $n$  increases, if the difference becomes positive for some year  $n$ , then the savings from disposal outweigh the savings from retention; and the decision is to retain  $n-1$  years of stock and dispose of all stock above that level.

### Expressions for Disposal Savings

The disposal savings for year  $n$  [ $DS(n)$ ] are the sum of the savings from not storing the stock and the disposal revenues. Mathematically, it is

$$DS(n) = SS(n) + SR, \quad [\text{Eq. 3-3}]$$

where

- $n$  = the year of stock being considered for retention
- $DS(n)$  = savings from disposing of stock for future year  $n$
- $SS(n)$  = accumulated storage savings from not storing stock for future year  $n$ , that is, the sum of storage costs for years 1 through  $n-1$
- $SR$  = the immediate salvage revenues from disposing of a year of stock (this expression is independent of  $n$  since we are assuming that disposal occurs immediately after the decision to dispose of stock).

Storage savings consist of a single expression that reflects the costs for storing the given year of stock until it is used:

$$SS(n) = \sum (f_i)(d)(s), \quad [\text{Eq. 3-4}]$$

where

- $n$  = the year of stock being considered for retention
- $SS(n)$  = accumulated storage savings from not storing stock for future year  $n$ , that is, the sum of storage costs for years 1 through  $n-1$
- $\Sigma$  = the summation of terms from  $i = 1$  to  $i = n-1$
- $f_i$  = the discount factor for year  $i$
- $d$  = the annual demand for the item
- $s$  = the annual cost to store a unit of the item.

Salvage revenues (or net savings from disposal) also consist of a single expression that reflects the costs of disposing of a year of stock:

$$SR = (d)(m), \quad [\text{Eq. 3-5}]$$

where

- $SR$  = the immediate salvage revenues from disposing of a year of stock (this expression is independent of  $n$  because we are assuming disposal occurs immediately after the decision to dispose of stock)
- $d$  = the annual demand for the item
- $m$  = the return from disposing of a unit of the item (computed as a percent of its value).

### Expressions for Retaining Stock

As previously discussed, the savings from retaining stock are a cost avoidance (namely, the avoidance of reprourement costs). Those savings can be put into one expression that encompasses the savings in materiel purchase costs (i.e., the value of the stock in the year it would need to be repurchased in) and the savings in the administrative costs to reorder an item:

$$RS(n) = f_n[(d)(u) + P], \quad [\text{Eq. 3-6}]$$

where

- $n$  = the year of stock being considered for retention
- $RS(n)$  = savings from retaining stock for future year  $n$
- $f_n$  = the discount factor for year  $n$
- $d$  = the annual demand for the item
- $u$  = unit price for the item
- $P$  = the administrative cost of procuring an item.

### Expressions for Demand

As noted earlier, we computed the demand  $d$  used in the equations above by straight lining the demand forecast for an item. We also applied an obsolescence rate of 8 percent<sup>5</sup> to that forecast to simulate the decline in demand from obsolescence. Consequently, the expected annual demand decreases with each new year considered by the model.<sup>6</sup>

<sup>5</sup> Historically, DLA has used obsolescence rates that ranged from 6 percent to 8 percent. We selected 8 percent as it would be the most conservative value in terms of retaining stock.

<sup>6</sup> In actuality, the use of an obsolescence rate also counters the tendency to over-forecast demand. Chapter 5 has more information on this tendency.

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## NET-PRESENT-VALUE RETENTION MODEL FOR REPARABLE ITEMS

The consumable model could be used for reparable items, but several questions arise:

- ◆ Should we use forecasted demand or forecasted condemnations as our demand stream feeding the model? Forecasted demand represents stock consumption from the customer side while forecasted condemnations represents stock consumption from the procurement side.
- ◆ Should we use acquisition price or repair price for the price of an item? The repair price represents the value of stock to the customer who turns in unserviceable stocks with a demand. The acquisition price represents the value of stock when it must be purchased from commercial sources.
- ◆ What obsolescence rate would be appropriate for reparable items? Across-the-board obsolescence rates are typically used for consumable items; but do they apply to reparable items, the complexity and nature of which may cause them to be redesigned rather than replaced?

Because all of these affect the model's application, we tested a number of variations of the basic model.

## LMI MODEL FOR REPARABLE ITEMS

A 1999 LMI report<sup>7</sup> documented a detailed study of Air Force retention levels. In that study we proposed a unique economic retention model with the following characteristics:

- ◆ Lower retention limits for unserviceable stocks than serviceable stocks, which is consistent with current Air Force policy.
- ◆ The use of demand to set limits for serviceable stocks and the use of condemnations to set limits for unserviceable stocks.
- ◆ Assignment of retention limits based on demand or condemnation frequency with items that have low frequencies receiving numeric limits.

Although we did not have the detailed demand data to replicate the frequency assignments, we simulated the assignments by using the presence of demand or condemnations in year 1 and year 2 to assign retention limits. We analyzed each of the characteristics—separately and collectively.

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<sup>7</sup> Logistics Management Institute, *Economic Retention Levels for Air Force Reparable Items*, Report AF701R1, Tovey C. Bachman and Robert E. Burleson, July 1999.

## Chapter 4

# Results

This chapter explains the results of our testing of all models with DLA and Air Force item groups. In all cases, the costs and savings shown are the sum of the respective costs or savings over the 7-year test period.<sup>1</sup>

Except for the extreme models, we tested each model with different parameter values to demonstrate how results changed as the parameter changed. In most cases, we displayed results of the zero-retention and retain-all models with the results for a particular model to show a relative range for judging the cost-effectiveness of that model.

In almost all cases, the retain-all model produced the highest level of savings. Toward the end of the chapter, however, we show statistics on inventory growth, which could negate the retention savings for the retain-all model.

### AT THE EXTREMES

The net savings for the zero-retention, retain-all, and perfect knowledge models are shown in Table 4-1.<sup>2</sup>

*Table 4-1. Overall Results for Extreme and Perfect Knowledge Models*

Model	Net savings for DLA consumable items (in millions)	Net savings for Air Force reparable items (in millions)
Zero retention	-\$855	-\$3,207
Retain all	\$655	\$102
Perfect knowledge	\$830	\$1,460

<sup>1</sup> Because we used the same values for each year of testing and were not concerned about the time value of money in our tests, we did not discount the costs by year.

We also excluded backorder costs. As noted in Chapter 3, the cost of a backorder is an intangible cost, which, for purposes of testing, we estimated as the value of the materiel backordered. However, because this estimate is questionable and it did not change the relative ranking of alternative models, we did not include it in our results.

<sup>2</sup> Appendix A provides a more detailed look at costs and savings resulting from our testing of the extreme models. In it we suggest the AAOs computed by DLA do not capture a large portion of its customer requirements, which are subsequently satisfied with retention stock. We also demonstrate that serviceable stocks for reparable items produce more savings than unserviceable stocks.

These results are somewhat surprising, as the retain-all model performed much better than expected. The zero-retention model is not cost-effective; therefore, it is not a viable alternative. This finding was not unexpected; policymakers have long supported the existence of economic retention based on past studies that have shown the same results.

## RESULTS FOR LEVELS-OF-STOCK MODELS

### Years of Demand

As noted in Chapter 3, the years-of-demand model relies on a demand forecast; therefore, we could only test the model for DLA QFD items and the Air Force-managed items.

We started our testing using 6 and 10 years of retention. We then increased the number of years, looking for the point at which savings would stop increasing and begin to decrease. We reached 100 years and savings were still growing. Using the zero-retention and retain-all models as reference points, the results for retaining different years of expected demand are shown in Table 4-2.<sup>3</sup>

*Table 4-2. Overall Results for Years-of-Demand Models*

Years of demand	DLA QFD items		Air Force-managed items	
	Net savings (in millions)	Savings per additional year (in millions per year)	Net savings (in millions)	Savings per additional year (in millions per year)
Zero retention	-\$236	—	-\$3,207	—
6 years	-\$69	\$27.9	-\$1,981	\$204.4
10 years	\$76	\$36.3	-\$1,612	\$92.3
20 years	\$180	\$10.4	-\$1,427	\$18.5
30 years	\$211	\$3.1	-\$1,398	\$2.9
50 years	\$231	\$1.0	-\$1,368	\$1.5
100 years	\$243	\$0.2	-\$1,334	\$0.7
Retain all	\$255	—	\$102	—

For DLA-managed items, the model is economical when the period of retention is more than a few years. Although the savings increase as the period of retention increases, the rate of increase (as indicated by the savings per increased year) slowed. Moreover, the retain-all model produced more savings in all cases.

<sup>3</sup> It could be argued that, because we did not include items that became obsolete or dropped out during the 7-year test history, we did not find a “turning point” (at which savings went from positive to negative with increasing numbers of years). However, as we stated in Chapter 1, stocks for obsolete items should be disposed of and not retained.

For Air Force-managed items, the results were the same except the model was not economical even when the period of retention is extremely high. This difference may be attributable to the condition of repair for reparable items.<sup>4</sup>

## Years of Demand Above the AAO

We list the test results for the variation of the years-of-demand model in Table 4-3.

*Table 4-3. Overall Results for Above-AAO-Years-of-Demand Models*

Years of demand	DLA QFD items		Air Force items	
	Net savings (in millions)	Savings per additional year (in millions per year)	Net savings (in millions)	Savings per additional year (in millions per year)
Zero retention	-\$236	—	-\$3,207	—
6 years	-\$86	\$53.7	-\$1,530	\$279.5
10 years	\$138	\$13.1	-\$1,434	\$24.0
20 years	\$196	\$5.7	-\$1,384	\$5.1
30 years	\$216	\$2.1	-\$1,367	\$1.7
50 years	\$233	\$0.8	-\$1,354	\$0.6
Retain all	\$255	—	\$102	—

For both sets of items, the results for the variation mirror the results for the simple years-of-demand model. A comparison of Table 4-2 and Table 4-3 shows that, as the number of years gets higher and closer to total retention (retain-all model), the savings between the two years-of-demand models get closer and closer. This occurs for two reasons:

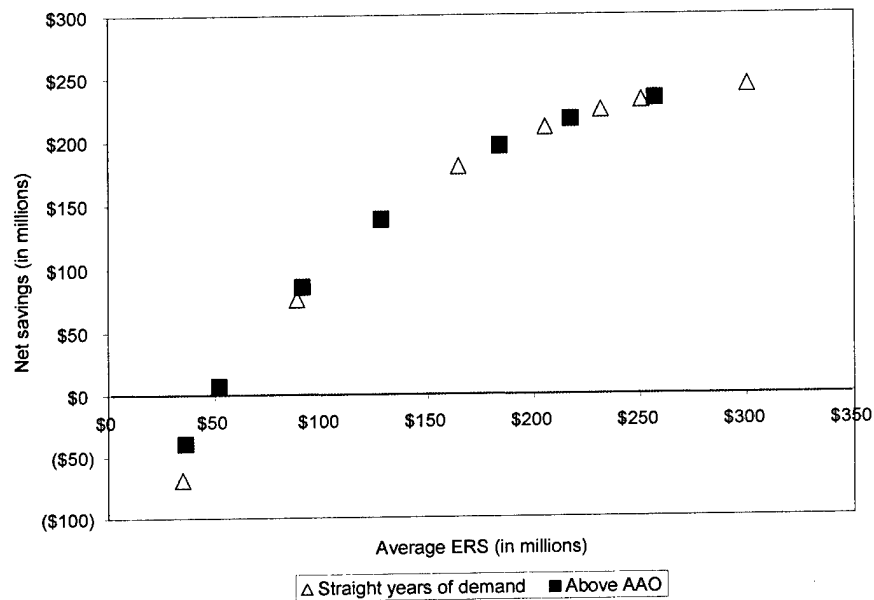
- ◆ As retention limits grow for either model, stock positions do not, and fewer items are affected by an increase in retention limits. Consequently, the savings differential between limits decreases. For example, if an item has 5 years of stock above the AAO requirement of approximately 3 years, going from a retention period of 10 to 20 years does not change the models' results for this item.
- ◆ The relative contribution of AAO to the overall retention level diminishes as the limits grow. Because the AAO is the difference between the two models, its relative impact on results grows smaller. For example, if an item has an AAO requirement equivalent to 4 years of stock, a 10-year retention period for the simple model and its variation would respectively be 10 and 14 years of stock, a 40 percent difference. A 50-year retention period would be 50 and 54 years of stock respectively, only an 8 percent difference.

<sup>4</sup> The 1999 LMI retention model for reparable items, introduced in Chapter 3 and discussed later in this chapter, illustrates what happens when different retention limits are applied to serviceable and unserviceable stocks.



These observations are illustrated in Figure 4-1, a scatter graph that plots each test run for the simple years-of-demand model and the above-AAO-years-of-demand model. Each point on the graph represents a test run where the *x* value for the point is the run's average ERS over the 7-year test period and the *y* value is its net savings. Comparing the two models, we see that, as the average ERS increases, they begin to coincide.

*Figure 4-1. Comparing the Two Types of Years-of-Demand Models*



## Numeric Levels

The test results for using numeric levels as retention levels for DLA NSO and non-stocked items are listed in Table 4-4.

*Table 4-4. Overall Results for Numeric-Level Models*

Value of X used to set numeric level	DLA NSO items (level = X × NSO quantity)		DLA non-stocked items (level = X units)	
	Net savings (in millions)	Savings per increased year (in millions per year)	Net savings (in millions)	Savings per increased year (in millions per year)
0 Zero retention	-\$581	—	-\$38	—
X = 6	-\$43	\$89.7	-\$19	\$3.1
X = 10	\$32	\$18.8	\$13	\$1.5
X = 20	\$92	\$6.0	-\$6	\$0.7
X = 30	\$112	\$1.9	-\$4	\$0.2
X = 50	\$125	\$0.7	-\$2	\$0.1
X = 100	\$132	\$0.1	\$0.2	\$0.04
Retain all	\$383	—	\$17	—

For both sets of items, the results are similar to the results for the simple years-of-demand model. Savings increase as the numeric level increases, the rate of increase declines. The retain-all model outperforms it in all cases.

## RESULTS FOR ECONOMIC MODELS

### Economic Model for Consumable Items

We began testing the economic model (results are shown in Table 4-5) for consumable items by allowing the model to use a maximum of 20 years of costs and savings to determine the optimal retention limit. The model determined that 56 percent of the items were at the 20-year cap. When we increased the cap to 30 years, 37 percent of the items were at the new cap. Finally, we increased the cap to 40 years, and 26 percent of the items were at this cap. We did not increase the cap again because the results from the 20-, 30-, and 40-year cap tests indicated that any further increase in cap would not produce a significant increase in savings.

*Table 4-5. Detailed Results for Consumable Item Economic Model*

Model	DLA QFD items (costs [-] and savings [+] in millions)				
	Net	Storage cost (-)	Usage savings (+)	Offset costs (-)	Disposal revenue (+)
Zero retention	-\$236	\$0	\$0	\$270	\$34
20 years	\$155	\$7	\$220	\$75	\$17
30 years	\$166	\$8	\$225	\$67	\$16
40 years	\$171	\$8	\$227	\$64	\$16
Retain all	\$255	\$24	\$279	\$0	\$0

Our results show the economic model was cost-effective; however, once again, the retain-all model performed better. Why? We attribute the lower performance of the economic model to its dependence on item demand forecasts to predict demand for extended periods into the future. The accuracy of the demand forecasts decreases as they are extended further into the future. (This point is discussed in Chapter 5.)

### Economic Models for Repairable Items

We tested the net-present-value model using the same 20-, 30-, and 40-year caps used for the consumable items.

## NET-PRESENT-VALUE VARIATIONS

The variations of the net-present-value model that we tested and our test results are shown in Table 4-6.

*Table 4-6. Results for Reparable Item Net-Present-Value Model*

Demand/price stream	Discount factor (percentage)	Obsolescence rate (percentage)	Retention maximum (in years)	Net savings (in millions)
Forecasted demand and repair price	10	8	20	-\$1,449
			30	-\$1,421
			40	-\$1,408
Forecasted condemnations and acquisition price	10	8	20	-\$349
			30	-\$349
			40	-\$349
	None	8	20	-\$319
			30	-\$319
			40	-\$319
	None	2	20	-\$309
			30	-\$270
			40	-\$241

Based upon the information in Table 4-6, we can conclude the following:

- ◆ All variations produce uneconomical solutions (i.e., negative savings).
- ◆ Using condemnation forecasts and acquisition prices (rather than demand forecasts and repair prices) in the model produces solutions that are better than years-of-demand solutions.
- ◆ Increasing the retention limit maximum generally improves solutions, just as it did for years-of-demand solutions.
- ◆ Discounting costs does not improve solutions.<sup>5</sup>
- ◆ Applying an obsolescence rate across all items does not improve solutions.

<sup>5</sup> This is probably due to the fact that discounting between years accentuates price as a driving factor. For example, a \$1,363.62 item had an 81 percent savings in the computed net present value between year 2 and year 22 when 10 percent discount factor was applied, but only a 58 percent savings when a zero-percentage factor is applied. This result is not surprising as the intent of using discounting is to include the time value of money in analysis.

However, in this case, it obviously drives less retention because future predictions for demand or condemnation are assumed to be correct. If they aren't, then less buffer stock is available to guard against under-forecasting.

## LMI MODEL FOR REPARABLE ITEMS

In Chapter 3, we discussed the three characteristics of the LMI model developed for the Air Force.<sup>6</sup> We tested all possible combinations of those characteristics as follows:

- ◆ Limits by condition (i.e., different limits for serviceable stocks [SSs] and unserviceable stocks [USs]).
- ◆ Limits based on demand for both SS and US or based on demand for SS and condemnations for US.
- ◆ Limits assigned by frequencies of demand or condemnations, that is,
  - High frequency (HF)—demands or condemnations in each of the last 2 years,
  - Medium or low frequency (MF)—demands or condemnations in only one of the last 2 years, and
  - Zero frequency (ZF)—no demands or condemnations in the last 2 years.

We should note that the actual LMI model tested in 1999 had four different frequency categories based on the number of quarters of demand. We had only annual data, therefore we reduced the number of categories and used similar—but not identical—frequency criteria.

The test results for our version of the LMI model are shown in Table 4-7.

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<sup>6</sup> Logistics Management Institute, *Economic Retention Levels for Air Force Reparable Items*, Report AF701R1, Tovey C. Bachman and Robert E. Burleson, July 1999.

*Table 4-7. Results of Initial Testing of Characteristics of  
LMI Reparable-Item Model*

Test	Different limits based on condition of stocks	Demand and condemnations	Assignments by frequencies	Net savings (in millions)
1	Yes SS = 20 years US = 10 years	No Just demand	No	-\$1,379
2	No All = 20 years	Yes Both used	No	-\$1,440
3	No All limits per frequency assignment	No Just demand	HF = 15 years MF = 20 years ZF = 15 units	-\$340
4	Yes SS = 20 years US = 10 years	Yes Both used	No	-\$1,455
5	Yes All limits per frequency assignment	No Just demand	SS HF = 15 years US HF = 8 years SS MF = 20 years US MF = 10 years SS ZF = 20-units US ZF = 10 units	-\$338
6	No All limits per frequency assignment	Yes Both used	HF = 15 years MF = 20 years ZF = 15 units	-\$197
7	Yes All limits per frequency assignment	Yes Both used	SS HF = 15 years US HF = 8 years SS MF = 20 years US MF = 10 years SS ZF = 20-units US ZF = 10 units	-\$235

From the data presented in Table 4-7, we can conclude the following:

- ◆ Assigning retention limits by frequency significantly improves savings.
- ◆ Using condemnations for unserviceable stocks and demand for serviceable stocks increases savings when combined with assigning retention limits by frequency.

Because tests 6 and 7 were the two lowest combinations and they were close, we ran more tests, increasing the retention limits in each to see if we could get positive savings. We increased the limits by 50 percent and then 100 percent, respectively. The results of these test are listed in Table 4-8.

Table 4-8. More Results on Characteristics of LMI Reparable-Item Model

Test	Different limits based on condition of stocks	Demand and condemnations	Assignments by frequencies	Net savings (in millions)
8	No All limits per frequency assignment	Yes Both used	HF = 22 years MF = 30 years ZF = 22 units	-\$184
10	No All limits per frequency assignment	Yes Both used	HF = 30 years MF = 60 years ZF = 30 units	-\$162
9	Yes All limits per frequency assignment	Yes Both used	SS HF = 22 years US HF = 12 years SS MF = 30 years US MF = 15 years SS ZF = 30 units US ZF = 15 units	-\$217
11	Yes All limits per frequency assignment	Yes Both used	SS HF = 30 years US HF = 16 years SS MF = 60 years US MF = 20 years SS ZF = 40 units US ZF = 20-units	\$205

Again, the net savings were negative; but they did improve. If we had the quarterly data that the 1999 LMI study used to assign retention limits, we might have been able to better simulate its model and produce positive savings. Using what we did have, we were able to prove that this approach produces better solutions than those from the earlier models we tested. Looking across all the test results in Table 4-7 and Table 4-8, a key characteristic of this approach is how it assigns limits by frequency.

## NO-DEMAND OPTION

The 2001 independent study highlighted periods of no demand as an important factor for stock retention.<sup>7</sup> That conclusion was based on the fact that items with previous long periods of no demand had a high probability of having no demand in the future.

Using the date of last demand, which is a data element for DLA items, we were able to test the no-demand option. For example, we tested the 7-year demand option by only assigning a years-of-demand retention limit to items that had demand within the last 6 years. To determine those items, we used the date of last demand

<sup>7</sup> Logistics Management Institute and Center for Naval Analyses, *Independent Study of Secondary Inventory and Parts Shortages*, Report LG009R1, July 2001, pp. 4-8–4-10.

at the beginning of FY1996. For items with no demand for 7 or more years, we assigned zero ERS.

In the course of our tests, we uncovered the fact that some items did not have a date of last demand (the field was blank) or the date they had for date of last demand was invalid (the field had a year, but no demand was recorded for that year in the item's demand history). This forced us to delete those items from our tests. The complete results for the remaining items are shown in Table 4-9.<sup>8</sup>

*Table 4-9. Overall Results for No-Demand Option*

Retention policy	Net savings for DLA QFD items with date of last demand (in millions)				
	Baseline	No retention for items that had no demand in indicated number of years or more.			
		5 years	7 years	9 years	12 years
QFD items—retain 0	-\$235.0	Same as baseline			
NSO items—retain 0	-\$501.6				
Non-stocked—retain 0	-\$30.5				
Total	-\$767.1				
QFD items—10 years	\$75.7	\$76.1	\$76.3	\$76.2	\$76.0
NSO items—10 × NSOQ	\$48.0	\$45.7	\$50.5	\$51.6	\$48.0
Non-stocked—10 units	-\$8.1	-\$9.3	-\$8.3	-\$8.1	-\$8.1
Total	\$115.6	\$112.5	\$118.6	\$119.8	\$115.6
QFD items—20 years	\$179.1	\$179.7	\$180.1	\$179.9	\$179.5
NSO items—20 × NSOQ	\$106.6	\$106.3	\$110.5	\$111.0	\$106.8
Non-stocked—20-units	-\$4.8	-\$5.8	-\$4.8	-\$4.6	-\$4.4
Total	\$280.9	\$280.2	\$285.8	\$286.2	\$281.9
QFD items—30 years	\$209.7	\$210.7	\$211.0	\$210.7	\$210.3
NSO items—30 × NSOQ	\$125.3	\$125.9	\$129.8	\$129.9	\$125.5
Non-stocked—30 units	-\$3.2	-\$4.1	-\$3.1	-\$3.0	-\$2.8
Total	\$331.9	\$332.4	\$337.6	\$337.6	\$333.0
QFD items—50 years	\$230.6	\$232.0	\$232.1	\$231.7	\$231.3
NSO items—50 × NSOQ	\$138.5	\$139.8	\$143.4	\$143.3	\$138.7
Non-stocked—50 units	-\$1.3	-\$2.2	-\$1.2	-\$1.1	-\$0.9
Total	\$367.8	\$369.6	\$374.3	\$374.0	\$369.0
QFD items—retain all	\$253.5	\$256.1	\$255.8	\$255.1	\$254.3
NSO items—retain all	\$329.5	\$315.9	\$335.6	\$338.3	\$331.2
Non-stocked—retain all	\$14.2	\$14.0	\$15.8	\$16.0	\$15.2
Total	\$597.1	\$586.0	\$607.1	\$609.5	\$600.7

<sup>8</sup> To include these results in Chapter 1 with the results for the other models, we used linear extrapolation to go from the smaller population to the full population.

From the extensive results in Table 4-9, we can conclude the following:

- ◆ Increasing the amount of stock retained for items increases savings across-the-board, with the retention of all stocks producing the largest savings.
- ◆ Using years of no demand to limit retention generally increases savings but not always.
  - Using a small number of years of no demand can reduce savings.
  - Using a large number of years of no demand can result in lower savings than using a smaller number of years.

The first conclusion under the years of no demand would seem intuitively correct: Using a short period of no demand would unnecessarily dispose of stock for items that have sporadic demand. However, the second conclusion seems counter intuitive if years of no demand is a good indicator of no future demand. But this is not because the finding has to do more with the potential for savings than the period of no demand.

The biggest area of savings from retention comes from using retained stock instead of repurchasing stock. As we increased the period of no demand, more and more stock was retained and usage savings increased until they reached their maximum. Depending on the scenario, usage savings reached that maximum usually at 7 or 9 years of no demand. Consequently, when we went to 12 years of no demand, we did not increase usage savings because they were at their maximum already.

When we went to 12 years of no demand, however, we did increase the amount of stock stored and decreased the amount of stock disposed of. These actions increased storage costs and decreased the return from disposal, respectively. Although the potential for offsetting buys did increase, the cost increase in this area was not enough to overcome the changes in the other two cost areas. The result was lower savings when using 12 years of no demand than when using 9 years of no demand.

## MINIMUM-LIMIT OPTION

Our numeric-levels models for low-demand and no-demand items suggest the possibility of adding a minimum numeric limit as an option to retention models. For example, if we required a minimum limit of 10 units of stock and the retention model called for 8 units of stock, we would raise the stock level to 10 units. If the model called for 12 units of stock, we would stay with 12 units of stock.

The minimum-limit option attacks the problem of demand variability as it provides for some retention even when the demand forecast is zero. Noteworthy is



the fact that our testing of the LMI model for Air Force reparable items used a minimum for zero-frequency items. The results are shown in Table 4-10.

*Table 4-10. Overall Results for Minimum-Limit Option*

Minimum limit	Net savings (in millions)			
	DLA QFD items— 20-year retention	Air Force items— 20-year retention	DLA NSO items— 20 × NSO quantity	DLA non-stocked items—20-units
Baseline—0 units	\$179.8	−\$1,426.9	\$92.5	−\$5.6
5 units	\$179.8	−\$175.8	\$248.4	\$0.2
10 units	\$179.8	\$94.4	\$271.4	\$2.6
20 units	\$179.9	\$162.1	\$287.1	\$4.3
Retain all	\$254.8	\$102.4	\$382.9	\$17.1

For fast-moving DLA QFD items, a minimum retention limit does little to improve savings. For other slower-moving items, however, having a minimum retention limit definitely improves savings.

For Air Force reparable items, the minimum-limit option actually produced greater savings than the retain-all model. Because the 1999 LMI model produced more savings than the 20-year retention model, we applied the minimum-level option to test 10 of the LMI model, which resulted in the following:

- ◆ With a 20-unit minimum on the retention level for serviceable stock only, the net savings increased from −\$162 million to \$361 million.
- ◆ With a 20-unit minimum on both the retention level for serviceable stock and level for unserviceable stock, the net savings increased from −\$162 million to \$384 million.

## INVENTORY GROWTH

A common assumption in evaluating retention models is the overall increase or decrease in stockage will not significantly affect overall depot storage costs, that is, no new depots will be added and no old depots will be closed. Value of inventory is sometimes used as a proxy for storage requirements. We examined the start and end values of inventories for our most cost-effective models and found the results listed in Table 4-11.

Table 4-11. Changes in Inventory

Item group	Model	Inventory value (in millions)		Difference
		Starting	Ending	
DLA QFD items	50 years of demand	\$887	\$815	-8%
	Retain all	\$887	\$1,005	13%
DLA NSO items	20 times NSO quantity with 20-unit minimum	\$1,432	\$1,034	-28%
	Retain all	\$1,432	\$1,540	8%
DLA non-stocked items	20-units with 20-unit minimum	\$61	\$170	180%
	Retain all	\$61	\$322	429%
Air Force reparable items	LMI model with 20-unit minimum	\$20,823	\$26,232	26%
	Retain all	\$20,823	\$33,609	61%

The results in Table 4-11 represent significant increases in inventory value for the retain-all model. If this increase in value translates to a similar increase in storage requirements, the long-term use of the retain-all model would require new warehouses and possibly new depots. The cost of acquiring such new storage space would be greater than the retention savings from using the model.

## PULLING IT ALL TOGETHER

The following summarizes our test results:

- ◆ For DLA consumable items, the retain-all model produced the highest level of savings, but also had significant increases in the value of on-hand inventory. Level-of-stock models with high parameter values produced the next highest levels of savings.
  - Employing the years-of-no-demand option slightly improved those savings.
  - Employing a minimum-level option improved savings for NSO and non-stocked items.
- ◆ For Air Force reparable items, the retain-all model did produce positive savings, but the minimum-level option significantly improved those savings. Combining the minimum-level option with a version of the 1999 LMI model produced the greatest savings.

The fact that keeping all of the existing stocks proved to be the most economical model for our 7-year simulation suggests that both DLA and the Air Force were retaining ERS that did have economic benefit, at least at the beginning of FY1996. The fact that levels-of-stock models with low parameter values and the

economic models were clearly outperformed by the retain-all model and the levels-of-stock models with high parameter values does not bode well for the military services and DLA that use these models in their management systems to set retention limits.

It also suggests those models are failing to capture a key element driving costs and savings: demand variability. Except for the retain-all model and 1999 LMI model, all the models we tested assumed stable and predictable demand patterns. The minimum-level option requires the retention of some stock, no matter the demand history and your predicted demand. The fact that it worked so well suggests that stable and predictable demand patterns are not prevalent.

In the next chapter, we look at the stability and predictability of demand over the 7 years we studied in our simulation.

## Chapter 5

# Demand Variability

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Inventory specialists, such as the American Production and Inventory Control Society, define demand as either independent or dependent. Demand found in manufacturing is dependent demand because it is directly related to the bill of material for producing an end product. For example, one windshield is needed to manufacture one car. Those demands can be calculated and need not be forecasted.

DoD materiel managers receive, for the most part, independent demands generated by equipment failures and customer consumption. They cannot be calculated and must be forecasted. These demand forecasts are the basis for most materiel management decisions, including retention decisions.

## HOW MUCH DOES DEMAND VARY?

### Assessing the Variability of Demand

In discussing DoD demand, the terms most often used suggest demand is somewhat stationary (it may vary, but it is fairly level from one year to the next). Thus, people talk about keeping 6 years of stock for any item versus 10 years of stock. Supposedly, the 6 or 10 years of stock would be equivalent to 6 or 10 years of demand, where demand is relatively stable over the respective periods.

But is the demand that DoD materiel managers see relatively stable from year to year? To answer that question, we looked at statistical measures of dispersion.

Except for items with little or no demand, we found that demand was not stable. On the contrary, we found extremely high demand variability. When we examined how this variability affects the years-of-stock determination, we found a high level of inaccuracy.

### Measuring Dispersion

Demand variance is a measure that statisticians use to quantify the dispersion of numerical data about its average value or mean. The ratio of the variance to the mean provides an index on how wide the spread is.

The Poisson distribution is a typical model used in inventory modeling to account for the variability of demand. That distribution has a variance-to-mean ratio of 1 because its variance equals its mean.

Using the 7 years of demand observed for each item, we computed ratios for each item. We found many items had ratios above 1, and the overall average was 32 for DLA items and 6 for Air Force items, both of which are much greater than a ratio of 1.<sup>1</sup>

## Probability of Similar Demand from Year to Year

Another way to look at demand stability is to examine how demand changes from one year to the next. An item with demand in a particular year, the demand in the next year was within 20 percent of that demand only 12 percent of the time for DLA items and 24 percent of the time for Air Force items. When an item had zero demand in a year, the next year it had zero demand 88 percent of the time for DLA items and 95 percent of the time for Air Force items.

These percentages support our finding of demand instability except in the case of items with no demand. It also provides some statistical evidence of why the no-demand option works so well.

## Determining Years of Stock

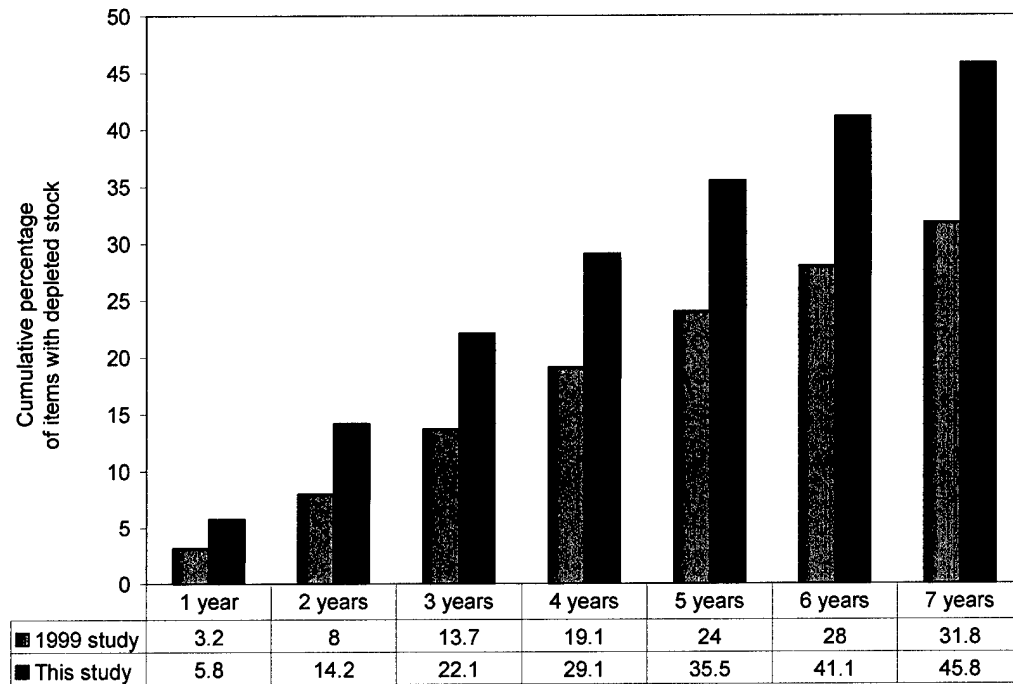
A 1997 LMI study of DLA economic retention policy<sup>2</sup> examined the validity of years of stock by giving every item stock equivalent to 6 years of forecasted demand and then looking at how long it actually took demand to deplete the stock. We repeated this analysis for the DLA items in our study. Figure 5-1 compares the results for the two studies.

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<sup>1</sup> See Appendix B for more on our variance-to-mean analysis.

<sup>2</sup> Logistics Management Institute, *Defense Logistics Agency Economic Retention Policy*, Report DL604R1, Karl Kruse et al., August 1997.

Figure 5-1. Actual Years Required to Deplete 6 Years of Stock



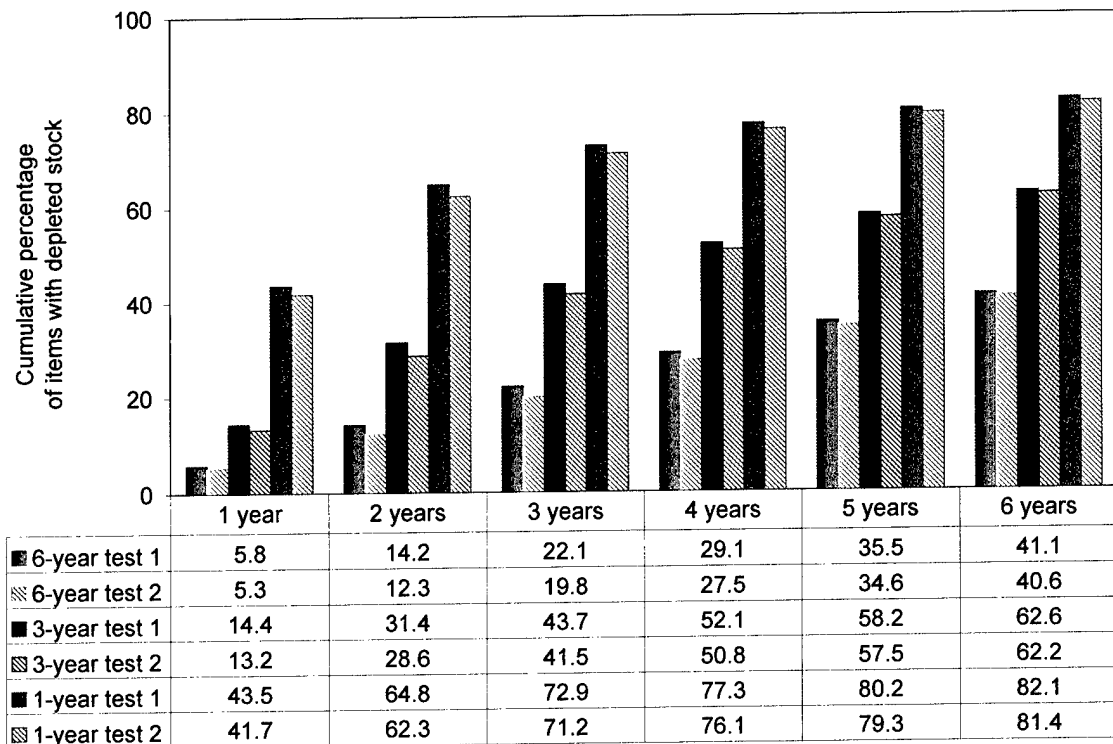
Although the analyses looked at 6 years of stock over different years, the end results were similar:

- ◆ The percentage of time that the predicted 6 years of stock was actually consumed in exactly 6 years was very small—4 percent of the time in the 1999 study and 5.6 percent of the time in this study.
- ◆ The percentage of time that 6 years of stock was actually consumed in 1 year was almost the same percentage of time it was consumed in 6 years—3.2–4 percent in the 1999 study and 5.8–5.6 percent in this study.
- ◆ In less than 50 percent of the time, 6 years of stock was actually consumed or depleted within 6 years.

It can be argued that these results should be expected because the forecasting models used in inventory control are generally short-term forecasting methods (i.e., methods designed to produce forecasts for 2–3 years rather than 6 years). It might also be argued that the starting point for our analysis biased the results (although the fact that we saw similar results for two different starting points weakens this argument).

To explore the merit of these arguments, we tested how long it would take to deplete 3 years of stock and 1 year of stock for two different starting points and 6 years of stock at another starting point. The results are shown in Figure 5-2.

Figure 5-2. Testing Actual Years Required to Deplete Years of Stock



The results for the second 6-year test were similar to the results for the first test. The two 3-year tests and two 1-year tests also produced nearly identical results. Therefore, the starting year doesn't seem to significantly affect the results.

Just like the 6-year tests, the 3-year and 1-year tests show that less than half of the stock is actually depleted in that time. Between 41.5 percent and 43.7 percent were depleted for the 3-year tests; and between 41.7 percent and 43.5 percent were depleted for the 1-year tests. Consequently, we concluded the shortness of the timeframe does not affect the accuracy of predicting years of stock.

## HOW DOES DEMAND VARIABILITY AFFECT MATERIEL MANAGEMENT?

### The Effect on Forecast Error

DoD materiel managers rely on models that use future program data (e.g., flying hours) and historical demand to predict demand. How does the high demand variability we have seen affect the performance of these models?

To answer this question, we conducted a simple test. Starting with an item with an average of 100 units per period and using single exponential smoothing as our forecasting model, we simulated what would happen to forecast error over 20,000 periods if we changed the variance-to-mean ratio. To generate demand, we used a random number generator and a uniform distribution based on the item's demand mean and variance. Figure 5-3 shows the results of increasing variance-to-mean ratios.

*Figure 5-3. Example of How Variance-to-Mean Ratio Affects Forecast Error*

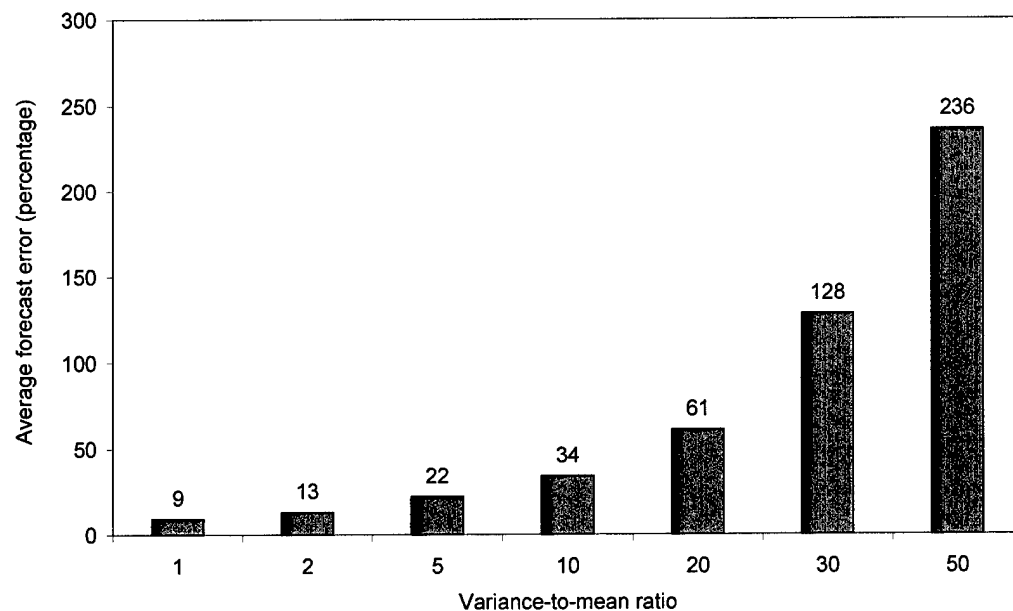


Figure 5-3 shows only one example of how increasing variance-to-mean ratios can significantly reduce the performance of forecasting models. If our example is indicative of what might happen with real items (and we have no reason to believe it is not), a variance-to-mean ratio of 163 would produce very high forecast errors.



## The Effect on Stock Management

In Chapter 2, we discussed how forecast errors translate to excesses and shortages in stock levels. We also talked about how economic retention reduces the costs that forecast errors could cause.

In Chapter 3, we described how many retention models rely on forecasts to set retention levels. When we tested those models in Chapter 4, we found that models and options that rely less on forecasts outperformed them.

Given the high levels of demand variability we quantified in this chapter, we can conclude that

- ◆ excesses and shortages are “the price of doing business” when it comes to DoD materiel management, and
- ◆ the ability to predict how many years of stock are in the system for a given item at a given point in time is very unreliable.

Our findings relative to the performance of different retention models and options seem valid.

## Appendix A

# The Detailed Results for Extreme Models

This appendix presents our test results for the extreme models. It provides several insights on factors affecting retention.

### DETAILED RESULTS FOR CONSUMABLE ITEMS

Table A-1 summarizes DLA consumable item results using the four costs and savings categories that went into the net savings from Table 4-1.

*Table A-1. Detailed DLA Results for Extreme and Perfect Knowledge Model*

Costs and saving	Extreme models		Perfect knowledge model
	Zero-retention	Retain-all	
Storage costs (-)	—	\$118,056,787	\$19,945,503
Usage savings (+)	—	\$772,797,403	\$772,797,403
Offset costs (-)	\$979,327,069	—	—
Disposal return (+)	\$123,952,632	—	\$76,819,288
Net	-\$855,374,438	\$654,740,615	\$829,671,188

As we expected, the perfect knowledge model outperformed the retain-all model. It had the advantage of keeping the stock that could be used to satisfy demand or offset procurements while disposing of all other stock. The difference in 7-year savings between the zero-retention model and the perfect knowledge model was more than \$1,685 million. Surprisingly, almost 90 percent of that difference was covered by the difference in savings between the zero-retention model and the retain-all model.

The overall cost-effectiveness of the retain-all model suggests that

- ◆ DLA is mostly retaining ERS for those items that have demand and thereby obtaining the associated usage savings, or
- ◆ the AAOs computed by DLA do not capture a large portion of the customer requirements that are subsequently satisfied with ERS.

When we looked more closely at the results for the retain-all model, we found that 42 percent of the items that started the simulation with ERS did not have procurement savings by the end of the simulation. For that to happen, those items would have had to have little or no actual demand during the simulation. This

finding would suggest the second reason—the AAOs do not capture the customer requirements—applies more than the first reason.

## DETAILED RESULTS FOR REPARABLE ITEMS

Table A-2 summarizes results for Air Force reparable items using the four costs and savings categories that went into the net savings in Table 4-1.

*Table A-2. Detailed Air Force Results for Extreme and Perfect Knowledge Models*

Costs and savings	Extreme models		Perfect knowledge model
	Zero-retention	Retain-all	
Storage costs (–)	—	\$1,419,336,888	\$496,019,697
Usage savings (+)	—	\$1,521,761,823	\$1,393,653,801
Offset costs (–)	\$4,409,070,858	—	\$8,846
Disposal return (+)	\$1,201,760,795	—	\$562,414,326
Net	–\$3,207,310,063	\$102,424,936	\$1,460,039,584

Again, with its advantages, the perfect knowledge model outperformed the retain-all model. In this case, the perfect knowledge model did have some offset costs. For consumable items, perfect knowledge of future demand allows for the retention of only items that will be used; however, for reparable items, unserviceable stocks can be retained to satisfied future demand, but they are actually not available to fill that demand because they are condemned during repair. Hence, it is better to dispose of those unserviceable items and incur offset costs rather than to retain them and incur repair costs but no usage savings.

Unlike the 90-percent coverage for consumable items, the retain-all model for reparable items only produced 71 percent of savings between the zero-retention model and the perfect knowledge model. The difference in percentages is largely attributable to the role of repair in the retention decision. When a serviceable item is demanded, normally an unserviceable item is turned in. That unserviceable item requires repair before it can be used to fill a future demand; and during that repair, it might be condemned and thereby have no future use. On the other hand, a serviceable item has the same probability of use and does not need to be repaired or condemned. This aspect of the reparable item supply support makes the retention of unserviceable ERS of less value than the retention of serviceable ERS.

Because the retain-all model does not distinguish between serviceable and unserviceable stock, it keeps unserviceable stocks that may have little or no value to reparable item supply support. Table A-3 demonstrates this by showing what would happen if unserviceable stocks were serviceable at the start of the test and vice-versa.

*Table A-3. Impact of Repair Status on Retain-All Decision (in millions)*

	Retain all	Retain all, but all stocks are serviceable at start of test	Retain all, but all stocks are unserviceable at start of test
Net savings	\$102	\$684	-\$109

Clearly, savings are strongly dependent on the condition of the materiel, as serviceable materiel produces more savings than unserviceable materiel.

## Appendix B

# Variance-to-Mean Ratios

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Using the demand that we observed in each of the 7 years of demand history we had for a DLA or Air Force item, we computed the mean (or average) demand per year and the variance from that mean. Using those two statistics, we then computed the variance-to-mean ratios shown in this appendix.

## DLA RATIOS

We looked at the average ratio across all DLA items and the averages for sets of items segregated by years of zero demand. Because each item had 7 years of demand history, an item could have 0 to 7 years with zero demand. Aside from the average ratio, we looked at the median and mode for each set to give us a more complete picture (Table B-1) of the dispersion within each set.

*Table B-1. Demand Variance-to-Mean Ratios for DLA Items*

Years of zero demand	Item count	Average ratio	Median	Mode (percentage of items in set with ratio equal to mode)
All items	1,068,540	32		
0	108,408	163	18	2 (6%)
1	54,071	74	9	1 (10%)
2	53,913	58	7	1 (12%)
3	61,281	48	6	1 (14%)
4	75,761	35	5	1 (23%)
5	100,928	22	3	1 (30%)
6	159,926	12	2	1 (37%)
7	454,252	0	0	0

Perhaps the most important set to look at is the set with 0 years of zero demand, as 0 tends to distort means and variances. It shows an average ratio of 163 and a median of 18—well above what is normally assumed to cover demand dispersion.

## AIR FORCE RATIOS

We also looked at the average ratio across all Air Force–managed items and the averages for sets of items segregated by years of zero demand. The results are listed in Table B-2.

*Table B-2. Demand Variance-to-Mean Ratios for Air Force Items*

Years of zero demand	Item count	Average ratio	Median	Mode (percentage of items in set with ratio equal to mode)
All items	101,747	6		
0	10,004	36	4	2 (15%)
1	2,479	29	3	2 (21%)
2	2,172	31	3	2 (20%)
3	2,318	16	3	2 (21%)
4	3,492	11	3	1 (22%)
5	4,577	8	2	1 (41%)
6	8,737	5	2	2 (43%)
7	67,968	0	0	0

Again, the average ratio for the set of items with the most demand is the highest at 36—well above the one normally assumed to cover demand dispersion. (The fact that, in all the sets, more Air Force than DLA items had a ratio equal to the mode is due to (1) lower demand quantities for Air Force than DLA items over the 7 years and (2) our rounding of the mode to the next integer.)

## Appendix C

# Abbreviations

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AAO	approved acquisition objective
COTS	commercial off-the-shelf
CRS	contingency retention stock
DLA	Defense Logistics Agency
DUSD(L&MR)	Deputy Under Secretary of Defense for Logistics and Materiel Readiness
ERP	enterprise resource planning
ERS	economic retention stock
GAO	General Accounting Office
HF	high frequency
MF	medium frequency
NSO	numeric stockage objective
QFD	quarterly forecasted demand
SS	serviceable stock
SSIR	Supply System Inventory Report
US	unserviceable stock
ZF	zero frequency